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Marine TacAir and the STOVL Penalty: Myth or Menace?

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EXECUTIVE SUMMARY

Title: Marine TacAir and the STOVL Penalty: Myth or Menace?

Author: Major John O. Jordan, United States Marine Corps

Thesis: The goals of the STOVL program, which include basing flexibility, mission effectiveness, and survivability, can be met by various means that (1) do not require STOVL capable aircraft, (2) exist within the current capabilities of military aviation, and (3) surpass the capabilities of STOVL.

Discussion: The Harrier program was originally designed to fill a need within the Marine Corps for a TacAir platform capable of operating from a large variety of sites, both on land and at sea. In addition, the aircraft needed to be survivable, supportable, maintainable, and capable of generating sorties at a rapid rate in support of the Marines on the ground. Historically, the STOVL program has faced many difficulties, as witnessed by the safety, survivability, and warfighting capability of the Harrier. The aftermath of the Harrier program has left many wondering about the utility of any STOVL program. As the Harrier Review Panel (HaRP) said, the AV-8B is a single-engine aircraft that is challenging to fly, difficult to maintain, a low priority within the Department of the Navy, and lags other aircraft in warfighting capabilities. Marine Corps decision-makers look to the Joint Strike Fighter to alleviate the shortcomings of the Harrier program, and to make Marine Aviation the all-STOVL force that our 21st Commandant had envisioned.

The JSF program was designed as a means of streamlining the acquisition, development, production, and support process within the military aviation services. The main goal of the program is to cut costs within the process, primarily by maintaining a high degree of commonality in an aircraft that will meet the needs of the Air Force, the Marines, and the Navy. The Marine Corps has stated a need for a STOVL version of the JSF as a replacement to the AV-8B and the F/A-18. Designers from Boeing and Lockheed Martin have attempted to answer the questions of the HaRP, but the evidence suggests that the STOVL JSF will still suffer some consequences of its design that will not be common to the other two JSF variants.

Conventional land and carrier based aircraft have demonstrated the capability to function better than the Harrier, from the sea and from forward deployed sites in combat. Simple, relatively inexpensive gear such as ski-ramps and arresting gear can further enhance the capability of conventional aircraft at a cost far less than developing and maintaining STOVL. The Harrier's trump card is its ability to operate from amphibious shipping.

Recommendations: True warfighting flexibility can only be attained by enabling all of the TacAir assets in both the Navy and Marine Corps to operate from very short runways and L-class ships. By modifying amphibious shipping to accommodate the carrier based JSF, the Navy-Marine team can employ not only the very few fixed wing assets of the MEU, but in fact all of the tactical air power of the Carrier Battle Group in the littorals where the carrier cannot go. This can all be achieved with today's technology and at less expense than developing a third, unique version of the JSF.

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STOVL JSF: THE CONTROVERSY

The STOVL JSF will bring to fruition the goal of an all vertical/short takeoff and landing (V/STOL) force, as first stated by the Corps' 21st Commandant, Randolph Pate.

Lt. General Fred McCorkle

In recent years, many articles and theses have been written concerning the usefulness of V/STOL aircraft in the various Armed Services of the U.S. From the ongoing saga of the MV-22 Osprey to the emerging technology of the short takeoff, vertical landing (STOVL) Joint Strike Fighter (JSF), the debate has entertained colorful arguments from across the spectrum of military aviators and Congressional budgeteers. Through all of the difficulties, the Marine Corps has led the way in the development of STOVL aircraft. Unfortunately, these projects have consistently been plagued by setbacks: safety, reliability, engineering challenges, budget cancellations, and others. The crux of the debate is whether the utility of STOVL is worth the cost, monetarily in terms of development, procurement and employment, and operationally in terms of survivability, payload, and combat range trade-offs.

The concept of a Vertical / Short Takeoff and Landing (V/STOL) fixed-wing attack aircraft, the original Harrier program, has been modified for the JSF, abandoning vertical takeoff capability in favor of a Short Takeoff / Vertical Landing (STOVL) design. Since the vertical landing requirement also brings limitations to the design and performance of the aircraft, the question is whether an aircraft capable of short takeoff and landing, but with no vertical capability, can fulfill the Marine Corps mission.

The design and performance limitations, known in aviation circles as the "STOVL Penalty," are pitted against the advantages of STOVL as major points of contention in the

controversy. On one hand, Department of Defense representatives state that STOVL is critical to the future of tactical aviation and that denying funding to the STOVL JSF program would deliver a crippling blow to the future of Marine Corps Aviation.¹ On the other hand, the so-called STOVL penalty is over-estimated, fueling the rhetoric of STOVL abolitionists. This polarity of opinions produces a passionate debate on the relative value of aircraft attributes as they relate to performance trade-off decisions. The issue of greatest import is not whether to embrace or abolish STOVL, but rather how the Marine Corps can best prepare itself to meet the needs of National Defense in a rapidly changing world. The objective of this thesis is to cultivate a better understanding of the capabilities and limitations of the STOVL concept, and to explore alternatives that could provide greater operational flexibility and performance at a lower overall cost.

This study will begin with a review of the original AV-8 program. Using the Harrier as a baseline, it will examine the goals originally set forth by the V/STOL program and assess the level of success with which those goals have been achieved. The Harrier Review Panel's First Annual Report will be used as a framework by which to structure the analysis. Then, the capabilities of both conventional and STOVL aircraft will be compared in order to assess their usefulness to the Marine Corps and its Expeditionary Maneuver Warfare concept. Finally, alternative solutions to the requirements of the STOVL program will be examined. The quest will help to form a more informed opinion of STOVL, and possibly find an answer to this question: Can the Marine Corps accomplish the goals of STOVL aviation without paying the STOVL price?

¹ Stacy Evers, "Cutting STOVL 'would cripple USMC aviation,'" *Jane's Defence Weekly*, 17 July 1996, 8.

AV-8 HARRIER PROGRAM: THE GENESIS OF TACAIR V/STOL

“It can be demonstrated that there are many missions in which the existence of various types of V/STOL aircraft can significantly enhance the capability of the military Services in carrying out their respective missions. Most of these are however, also susceptible to various other solutions, and none that the Task Force considered, is so demonstrably uniquely improved by V/STOL as to absolutely demand its adoption.”

Defense Science Board Final Report, 1979

In 1979, the Defense Science Board conducted a review of the Vertical/Short Takeoff and Landing (V/STOL) program. Their specific task, as assigned by the convening letter, was to “Review past V/STOL programs and evaluate why they have failed to produce a meaningful military capability.”² In the wake of the near disastrous beginnings of V/STOL tactical aviation, the AV-8 program came under close scrutiny. The Secretary of Defense struggled with the issue of continuing the Harrier program with the improved AV-8B. When the final decision was made, it was “the large number of potential mission improvements coupled with the need to increase survivability and flexibility that [built] the convincing case for continued consideration and development of a V/STOL capability.”³ What the V/STOL program promised to bring to the warfighting table were flexible basing options, high sortie rates, and survivability. The Board recognized these needs as valid, yet questioned the V/STOL program as the preferred method by which to meet them.

FLEXIBLE BASING

Fixed wing aviation assets require a tremendous amount of support in the form of runways and taxiways, maintenance facilities, and storage and support equipment for fueling and

² Office of the Under Secretary of Defense for Research and Engineering, *Final Report of the Defense Science Board Task Force on V/STOL Aircraft* (Washington, D. C.: November 1979), 43. Cited hereafter as Defense Science Board, 1979.

³ Defense Science Board, 1979, 13.

ordnance. Possibly the most significant of these variables is runway length. Figure 1 provides a comparison of various tactical aircraft and their runway requirements:

Short Takeoff Capability at Combat Weight:

A-10	3168 feet	9500 lb. external stores, full internal fuel
F-15	2158 feet	4000 lb. external stores, full internal fuel
F-16	2600 feet	3000 lb. external stores, full internal fuel
F-18	2658 feet	6200 lb. external stores and fuel, full internal fuel.

Short Field Landing Capability, 4000 lb. total fuel and external stores:

A-10	1396 feet
F-15	4300 feet
F-16	2831 feet
F-18	4700 feet

(Figure 1) ⁴

By reducing the length of runway required for takeoff and landing, V/STOL capable aircraft can raise the number of land basing options appreciably. In 1979, airfield data for West Germany, Luxembourg, Belgium, and the Netherlands indicated 476 airfields with runways of 1000 feet or more, but only 102 with 5000 feet or more.⁵ A more current survey of 14 third world countries reveals that airfields with 2,000-foot runways outnumber those with 8,000-foot runways by a factor of 10.⁶ While none of this data takes into consideration the composition and load rating of the runways, which will definitely impact their usefulness to both conventional and STOVL aircraft, it does demonstrate the dramatic increase in basing options that short takeoff and landing capability provides. Hidden within these numbers, however, is the enormous flexibility of our existing conventional air fleet, and the idea that having the V in STOVL may not be necessary to achieve the desired effects.

⁴ Source: Combat Flight Planning Software. Data provided is at sea level, under Standard Day conditions. External Stores weights were calculated using typical load-outs for Desert Storm Air-to-Ground sorties for each aircraft.

⁵ Defense Science Board, 1979, 77.

⁶ Theodore Herman, "Marine Expeditionary Air Operations: A Case for V/STOL Aviation," *Marine Corps Gazette*, May 1999, 49.

HIGH SORTIE RATES

The bottom line requirement for Marine tactical aviation (TacAir) is to provide fire support to the ground commander by placing a high volume of ordnance on target in a short amount of time. The conceptual advantage of V/STOL is to enable the aircraft to operate close to the front lines, and thereby reduce the transit time between refueling and rearming points and the target area. What V/STOL aviation can provide, that conventional and carrier-based aircraft cannot, is the ability to land and takeoff from almost anywhere. Forward Arming and Refueling Points (FARPs) can be established in remote, concealed sites near the front lines. Amphibious ships can provide fixed wing air support near established beachheads. Conventional bases can be used even if the runways have been damaged. Road segments can be converted into makeshift runways. Austere sites such as grass fields can be established closer to the battle. The whole concept of V/STOL is based on attack force efficiency: maintaining a high sortie rate, quick response time, and high total ordnance on target, even when runways have been damaged and conventional aircraft are incapable of operating.⁷ In concept, STOVL meets the requirement for high sortie rates by operating close to the battle. But, the logistical effort required to make the concept a reality is tremendous, and contributes to a significant weakness of the Marine Corps' STOVL programs: survivability.

SURVIVABILITY

The Defense Science Board stated that a primary reason to pursue the development of V/STOL aircraft was the vulnerability of air facilities. “Main operating air bases and aircraft carriers are prominent, unconcealable, easily targeted, and subject to attack from a variety of long range weapons.”⁸ The basing flexibility afforded by V/STOL and future short takeoff,

⁷ Defense Science Board, 1979, 67-70.

⁸ Defense Science Board, 1979, 9.

vertical landing (STOVL) aircraft can complicate the enemy's targeting problem and significantly improve the survivability of air bases in a combat theater. This survivability, promoted as a unique provision of the V/STOL program, is expected to come from three features. First, an airfield at risk of an enemy attack should be able to displace quickly, re-establish itself in a different location, and retain its combat effectiveness. "Easily displaced advanced expeditionary airfields and advanced forward arming and refueling points, combined with VSTOL and rotary wing aircraft will give the MAGTF commander the unique flexibility to employ his aviation in order to most efficiently accomplish the mission."⁹ Second, by utilizing a larger number of dispersed sites, an attack on any given airfield will have less effect on the total aviation combat force. Finally, V/STOL aircraft have the unique capability of operating on airstrips that have been damaged by enemy attacks without suspending operations for repair or displacement. What the Board did not address was the difficulty in providing force protection of the airfields and supply trains, particularly in an increasingly asymmetric threat environment. Large, centralized bases may have an advantage in that arena. Also, airfields are only part of the survivability story. The other part is aircraft survivability, an area in which the engineering restrictions of previous STOVL designs lag significantly behind conventional aircraft.

THE STOVL GENESIS

The AV-8B Harrier program promised to provide a TacAir solution to the requirements of the V/STOL program. Its direct lift, vectored thrust design and advanced targeting systems showed great promise in providing basing flexibility and survivability while delivering a high volume of accurate fires in support of the ground combat element. The 1979 Defense Science Board conference reviewed the potential of the AV-8B as a tremendous improvement to the AV-

⁹ Concepts Division, Marine Corps Combat Development Command, *United States Marine Corps Warfighting Concepts for the 21st Century* (Quantico, VA: 1998), IV-11, 12.

8A. A presentation to the Board highlighted the proven advantages of V/STOL as demonstrated by the performance of the AV-8A, including praises to the Harrier program for its “outstanding safety record.”¹⁰ Ironically, the AV-8A ended its fleet tour with an abysmal safety and performance record, passing many of its shortcomings on to the AV-8B. In the final report, the Board expressed its doubts as to the uniqueness of V/STOL TacAir as the provider of flexible basing: “It is, however, not clear at this time that the increment in basing flexibility achievable with such a machine over that available through the use of improved high lift devices and arrestment systems will warrant the cost of development of such a machine.”¹¹ When the dust settled, Congress approved funding of the AV-8B, and the Harrier program continued. Many would say that the cost of the program was not warranted, in spite of the lofty claims of its early promoters.

Sixteen years later, the Harrier was a combat proven airframe, having undergone many trials across the spectrum of conflict, from Desert Storm to Bosnia. Recognizing the shortcomings of the V/STOL program, the Marine Corps abandoned the requirement for vertical takeoff and commissioned Lockheed Martin and Boeing to design Short Takeoff, Vertical Landing (STOVL) versions of the Joint Strike Fighter (JSF). Still, the STOVL JSF project faced extinction because V/STOL and STOVL TacAir had not yet proven a unique ability to provide effective air support when no other airframe could. “The House version of the FY97 defence budget authorisation (sic) prohibits spending money for a STOVL variant [of the JSF] and requires an analysis of force structure alternatives and associated costs.”¹² With all of its potential, the Harrier program ended the century leaving serious doubts as to the ability of a

¹⁰ Defense Science Board, 1979, 68.

¹¹ Defense Science Board, 1979, 26.

¹² Evers, 8.

STOVL fixed wing attack platform to perform on par with its conventional and carrier based brothers.

The reasons to pursue STOVL are clear. The Marine Corps needs a TacAir platform that is flexible, survivable, and able to provide a high volume of accurate fires in close support of the Marine on the ground. After over two decades of performance, not only in peacetime, but also in many levels of conflict, the Harrier program faces attack from many fronts, and indeed the utility of any STOVL TacAir platform is in doubt. Part of this doubt comes from the fact that, as the Defense Science Board pointed out, other solutions exist which would employ more conventional and less expensive options.¹³ The other, more prevalent causes of this doubt are the many shortcomings of the Harrier program (real or perceived), and the fear that those shortcomings will be inherited by the STOVL JSF.

¹³ Defense Science Board, 1979, 26.

THE HARRIER: A MARINE AVIATION ICON

Virtually unknown to the general public, Marine Harriers were in the fray from beginning to end. They based close to the battle, on land and at sea, as they had always advertised they would, and delivered significant amounts of ordnance. Their missions were varied: battlefield air interdiction, helicopter escort, battlefield preparation, and close air support. Flying every mission for which they were tasked, they never required aerial refueling as they ranged over Kuwait.

LtCol. Theodore N. Herman, U.S. Marine Corps (Retired)

The AV-8B Harrier is a continuous source of controversy among aviation experts. On the one hand, the Harrier and the STOVL program in general are upheld religiously as the savior of Marine Corps TacAir. In a formal appeal to Congress, the U.S. Department of Defense pleaded that denying funding for the development of a STOVL variant of the JSF would “deliver a crippling blow to the future of Marine Corps aviation.”¹⁴ LtCol. Theodore Herman, a former USMC Harrier squadron commander and a Manager of Business Development for Boeing’s Joint Strike Fighter program, provides a steady stream of articles to various professional military periodicals such as *Proceedings* and *Marine Corps Gazette*, praising the STOVL program:¹⁵

“Flexible, light but lethal, responsive, and survivable air support are the requirements for today’s expeditionary forces; V/STOL aviation provides the edge in spades whether it be in a conventional or expeditionary role. It is MAGTF [Marine Air Ground Task Force] aviation.”¹⁶

LtGen. Fred McCorkle, serving as the Marine Corps’ Deputy Commandant for Aviation, stated that the STOVL JSF is fundamental to our TacAir modernization plans.¹⁷ This view is widely held not only within the Marine Corps, but also in the civilian aviation community.

¹⁴ Evers, 8.

¹⁵ Theodore N. Herman, “Why Single-Engine STOVL?,” *Proceedings*, April 2000, 77.

¹⁶ Theodore N. Herman, “Marine Expeditionary Air Operations: A Case for V/STOL Aviation,” *Marine Corps Gazette*, May 1999, 50.

¹⁷ Lt.Gen. Fred McCorkle, “Building Marine Aviation for the 21st Century,” *Marine Corps Gazette*, May 1999, 23.

Aviation literature is replete with rhetoric, often in the form of theoretical musings and anecdotal evidence, that supports STOVL as the effective and reliable backbone of Marine Corps TacAir.

On the other hand, a significant amount of literature has been presented in opposition to the Marine STOVL program and particularly to the AV-8B Harrier. LtCol. Jay Stout, author and prolific opponent of STOVL, presents an argument that is the antithesis of the Marine Corps party line:

“The Marine Corps’ planned acquisition of a STOVL (short takeoff vertical landing) version of the Joint Strike Fighter (JSF) will saddle the service with an aircraft that is less capable, more expensive, and comparably more difficult to maintain than the more conventional JSF versions which will be bought by the Air Force and the Navy. These drawbacks, suffered for the sake of a capability whose utility is doubtful, may well cripple the Marine Corps’ future tactical jet program.... Critics will say that if the Marine Corps gives up on V/STOL and STOVL, then it will lose a special niche that makes it unique; that without this capability, the very existence of Marine Corps tactical jet aviation is in jeopardy. And that (sic) having tactical jet aviation is what enables the service to survive separately from the Army and the Air Force. If that is the case; if our survivability is dependent on an expensive, overweight, poorly performing vertical lift fixed wing aircraft, then we’ve got real problems.”¹⁸

Because of the history of problems in the Harrier program, STOVL has accumulated many opponents within the Military Aviation community. In an effort to reduce the AV-8B mishap rate and enhance community confidence in the Harrier, the Commandant of the Marine Corps established the Harrier Review Panel (HaRP) in 1997.¹⁹ A formal review of the Harrier program revealed that “when compared to other DoN [Department of the Navy] tactical aircraft, the AV-8B remains a single engine airplane, which is challenging to fly, difficult to maintain, and which, because of its relatively low priority within DoN, lags other aircraft in warfighting capabilities.”²⁰ The Harrier program did not prove to be all that the Marine Corps hoped it

¹⁸ Jay A. Stout, LtCol, USMC, “STOVL and JSF: Let’s Not Handicap a Winner,” *Marine Corps Gazette*, May 1999, 45.

¹⁹ Commandant of the Marine Corps, message to Deputy Chief of Staff for Aviation, subject: “Establishment of a USMC Harrier Review Panel,” 3700 APP4, 7 November 1997.

²⁰ Harrier Review Panel, *HaRP First Annual Report (1997)*, HQMC.MIL/HARP, URL: <www.hqmc.mil/harp.nsf/>, accessed 12 October 2000, 3. Cited hereafter as HaRP First Annual Report.

would be, but does that mean the STOVL JSF will also fall short of expectations? Many opponents of STOVL have transferred the maladies of the Harrier directly to the STOVL JSF in their attacks of the program.

Both sides of the STOVL argument hold an element of truth. It is undeniable that having an abundance of basing and FARP possibilities provides increased flexibility to an air component commander. But it is equally undeniable that the issues of flexible basing, high sortie rates and survivability may be answered by a variety of means that do not necessarily require a STOVL aircraft. The objective, then, is to conduct a review of the STOVL program, in relation to other available alternatives, in order to determine how to best meet the requirements of Marine TacAir. The first step is to review our current STOVL program to determine its relative value to the Marine Air Ground Team. As problems with the program are identified, an assessment will be made as to whether that problem is peculiar to the Harrier airframe, or possibly common to our future STOVL efforts.

PERFORMANCE REVIEW: HAS STOVL ANSWERED THE MAIL?

There is some work we have to do in the Harrier. It is not a fragile airplane. We turned that thing in excess of two to four times a day for almost the whole campaign, so it really stayed up. I got exactly what I wanted out of it. We did a lot of forward basing with it and the F/A-18. Half the AV-8B sorties stopped at Tanajib instead of going back to Aziz, and half the F/A-18 sorties came back and stopped at Jubayl instead of going all the way back to Shaik Isa. So we used a lot of concepts. I'm very happy with the Harriers' performance, but we've got some work to do.

*LtGen. Royal N. Moore, Jr., USMC
U.S. Naval Institute Proceedings Interview, November 1991*

In the history of Marine Corps aviation, across the entire spectrum of conflict from Guadalcanal to Somalia and every point in-between, fixed wing and rotary wing assets have provided air support to the Marine ground combat element. They have done so with responsiveness and effectiveness, independent of the presence of STOVL TacAir. By utilizing aircraft carriers and expeditionary airfields, refueling from airborne tankers, and by sheer strength of payload capacity and combat radius, Marine fixed wing and helicopter assets have answered the call every time. The ever-present questions are, can we do it better, and can we do it cheaper. The goal of STOVL is to do it better; the goal of the JSF program is to do it cheaper. By combining the two, the Marine Corps hopes to find in the STOVL JSF an aircraft more capable and more affordable than ever before.

“The JSF Program is the Department of Defense’s focal point for defining affordable next generation strike aircraft weapons systems for the Navy, Air Force, Marines, and our allies. The focus of the program is affordability—reducing the development cost, production cost, and the cost of ownership of the JSF family of aircraft.”²¹

²¹ John H. Pylant, Capt, USMC, “Joint Strike Fighter: Joint Vision or Joint Illusion?,” *Marine Corps Gazette*, May 1999, 44.

The goal is to accomplish all of this with an aircraft that does not suffer the shortcomings of the Harrier. The STOVL JSF program maintains that it has resolved all of the problems identified by the HaRP in its review of the Harrier.²² Still, many of the difficulties of STOVL aviation do not relate directly to the type of aircraft in question, but rather to the concept itself, which boils down to a battle between technology and physics.

In a conventional aircraft, lift is derived by creating a differential in air pressure as it flows over the wing. To make an aircraft land vertically, all of that lift must come in the form of thrust from the engine or a lifting fan. Creating that thrust requires large amounts of fuel. Fuel adds weight to the aircraft, which in turn requires more thrust. For an attack aircraft, weapon loads also add significant weight to the thrust burden of vertical flight. The engineering answer to the vertical requirement is to make a lighter weight aircraft, which means less fuel and weapons. Without lightweight alternative energy sources and small weapons with big punch, STOVL aircraft will not perform as well as conventional aircraft. In the absence of this technology, V/STOL and STOVL programs attempt to minimize the effects of reduced payload and combat radius caused by the requirement of vertical flight. By looking back at the original goals of the V/STOL program, (flexible basing, high sortie rates, and survivability) one can assess the degree of success with which the Harrier met these needs, and also speculate on how well the STOVL JSF may perform in support of the ground combat element.

BASING OPTIONS

As outlined earlier, the number of airfields potentially available for combat operations throughout the world increases dramatically as the required runway length is decreased. Unfortunately, runway length is only part of the story. Other issues, such as fuel and ammunition supply, maintenance facilities, and site security can be a tremendous hindrance to

²² Herman, *Proceedings*, April 2000, 77.

the size and location of suitable airfields. To date, the Harrier has not routinely operated, in combat or in training, from land bases that were not suitable for use by conventional TacAir platforms such as the F/A-18, F-16, and A-10. A statement from an experienced Harrier pilot illustrates this point:

“[T]he only two-lane road that the vast majority of USMC Harrier pilots have ever flown off of or landed on is Lyman Road in Camp Lejeune, N.C. In my own personal experience involving 1,300 hours of Harrier flight time which includes two deployments to the Mediterranean, a Western Pacific deployment, and Desert Shield/Desert Storm, I have never landed on a road or austere VSTOL pad except at Camp Lejeune.... Except to prove the concept, USMC AV-8Bs do not operate off of grass strips either. If STOVL jets will take-off with full internal fuel and any significant payload, then a lot more than just a pad is needed.”²³

Still, the Marine Corps emphasizes its need for this capability in its publication on Warfighting Concepts for the 21st Century: “Our combat aircraft must be capable of operating from a variety of ships and austere bases ashore, perform a variety of missions, and land on a wide variety of surfaces.”²⁴ Harrier proponents often cite the performance of the AV-8B during Desert Storm as a demonstration of its ability to fulfill this need.

“During Desert Storm, Harriers, forward-based at King Abdul Aziz Airbase, Tanajib (42 miles from the front) in Saudi Arabia and on the USS *Nassau*, freed up scarce space at larger bases for conventional aircraft.... The Harriers provided such a significantly flexible and responsive air cover and harassment of the Iraqis that Secretary of Defense Richard Cheney named the Harrier one of the three most significant weapons systems in the Gulf War—STOVL more than proved its worth.”²⁵

King Abdul Aziz Airbase had an 8,000-foot concrete and asphalt runway already in place, and the FARP at Tanajib had an existing 6,000-foot runway.²⁶ Both of these airfields were capable of conventional aircraft operations, and were further improved by the engineering

²³ Ben D. Hancock, Maj, USMC, *The STOVL Joint Strike Fighter in Support of the 21st Century Marine Corps*, Thesis (Quantico, VA: United States Marine Corps Command and Staff College, 14 April 1997), 16.

²⁴ *United States Marine Corps Warfighting Concepts for the 21st Century*, I-20.

²⁵ Herman, *Marine Corps Gazette*, May 1999, 49.

²⁶ Theodore N. Herman, “Harriers in the Breach,” *Proceedings*, February 1996, 46.

efforts of the Marines and Seabees. The Harrier, along with many conventional aircraft types, fulfilled the needs of the Marine Corps in Desert Storm. To call the aircraft one of the three most significant weapons systems in the Gulf War is an overestimate of the utility of STOVL in that conflict.

This is not to say that the Harrier cannot produce land-based sorties from sites that are prohibitive to conventional TacAir assets, rather that it has rarely done so in combat or in training. This fact has two principal causes. First, the surface type of the landing area plays a big factor in its usefulness to STOVL aircraft.

“When operating from unprepared surfaces, such as grass clearings or asphalt roads, the effect of vertical jet blast is swift and destructive. Since the exhaust is deflected downward in a hover or slow flight, a STOVL jet can dig a hole and tear up huge chunks of asphalt and flying debris that can either damage the airframe or be ingested into the engine.... The increase in thrust for the JSF (35,000 pound-thrust class engine versus 23,000 pound-thrust class for the Harrier) will increase the energy directed on the landing surface and may increase the possibilities for self-induced FOD.”²⁷

The second reason for using larger, prepared surfaces for STOVL operations is the length of runway needed for the Harrier to take off with a significant combat payload. A brief to the Defense Science board stated that an AV-8B performing a vertical takeoff with a combat load of six MK-82 bombs would have a combat radius of only 24 nautical miles because of fuel limitations. With a takeoff roll of 1000 feet, however, the Harrier could carry a load over twice that size over a radius of 203 nautical miles.²⁸ As runway length increases, the combat capabilities of the Harrier increase dramatically. This fact, along with the need for an adequate airfield support infrastructure, drives aviation planners to place Harriers in locations that are typically suited to conventional TacAir operations. Yet, as the United Kingdom Ministry of Defence briefing to the Defense Science Board pointed out:

²⁷ Hancock, 17.

²⁸ Defense Science Board, 1979, 78.

“If the runway length needed by conventional aircraft is available, vectored-thrust VSTOL aircraft can be operated conventionally and, up to the limit of their weapon attachment points’ capacity, can have similar payload/range performance as an otherwise equivalent conventional aircraft. The vectored-thrust VSTOL aircraft, however, can continue to operate, with reduced payload or range, when operating surface length becomes too short for conventional aircraft to operate at all.”²⁹

With the vertical takeoff capability of the Harrier, this is true, and while the STOVL JSF is not designed for vertical takeoff, its short takeoff roll will provide an advantage over conventional aircraft in this regard. The employment of runway “ski-jumps” could further enhance this advantage, and could also improve the short takeoff capability of conventional aircraft.

Another advantage of the STOVL program is the ability to operate from L-class ships. STOVL aircraft have the ability to operate from twice as many naval platforms as conventional aircraft.³⁰ Some Desert Storm Harrier Squadrons were based at sea and used creative ways to minimize the limitations associated with shipboard operations. The USS *Nassau* operated as a “Harrier Carrier,” performing STOVL operations exclusively.³¹ This increased the fixed wing sortie rate, and was developed as a way to alleviate the difficulties of operating Harriers and helicopters concurrently from amphibious shipping.³² Under most circumstances, however, a MEU will be required to conduct concurrent or phased fixed wing and helicopter operations, and will not have the ability to exclude helicopter operations in favor of TacAir. Certainly, twenty Harriers operating unencumbered from the deck of an LHA has a very different firepower effect than do six Harriers sharing deck operations with helicopters. Still, no other fixed wing asset can

²⁹ Defense Science Board, 1979, 71.

³⁰ McCorkle, “Building Marine Aviation for the 21st Century,” 24.

³¹ Hancock, 35.

³² Hancock, 34.

operate from amphibious shipping, and the Harriers from the USS *Nassau* were assets that may not have been available were it not for that unique capability.

The Harrier does, in fact, increase the basing options available to the Air Component Commander. Its unique ability to operate from damaged airfields, and particularly from amphibious shipping has been demonstrated with considerable success. But, because of the payload and fuel penalties of performing vertical takeoffs and landings, land basing options have most often been common to those of conventional TacAir. As for the future of STOVL, if technology progresses as predicted, we can score flexible basing options in the plus column for STOVL JSF.

SORTIE RATES

The whole concept of STOVL is based on attack force efficiency: maintaining a high sortie rate, quick response time, and high total ordnance on target, even when runways have been damaged and conventional aircraft are incapable of operating.³³ The Gulf War is America's only example of large-scale, sustained combat by which to compare the sortie rate performance of STOVL against conventional aircraft. The Harrier performed very well in that conflict, operating from bases in close proximity to the Kuwaiti border. Many conventional aircraft did the same. Hornets based at Shaik Isa utilized the airfield at Jabayl as a FARP, just as the Harriers did at Tanajib, thus reducing transit time to and from the target area.³⁴ F-16s from the 363d Tactical Fighter Wing generated a tremendous number of sorties while operating from a forward operating location (FOL) at King Khalid Military City (KKMC) in Saudi Arabia, located just 60 miles from the Iraqi border.

“F-16s operating there were able to exchange their drop-tanks for extra ordnance: KKMC-based missions carried four Mk-84 2,000-pound bombs (double the normal load

³³ Defense Science Board, 1979, 67-70.

³⁴ “Marine Air: There When Needed,” *U.S. Naval Institute Proceedings*, November 1991, 126.

of two). FOL operations allowed the wing to fly more sorties per day; KKMC missions launched from the 363d main base in Abu Dhabi to bomb the KTO [Kuwait theater of operations]; landed and rearmed at KKMC for a second sortie to the KTO (which did not require refueling); landed and rearmed at KKMC for a third mission and after attacking the KTO, air refueled to return to Abu Dhabi.”³⁵

By forward basing, the highly capable F-16 carried a larger payload than either the Harrier or the Hornet, and delivered tons of ordnance into Kuwait with a very small transit and turnaround time. This is a great example of maximizing conventional technology to fulfill the expeditionary needs of the Armed Services.

Another platform that played a significant role in increasing the sortie rate of fixed wing assets was the Forward Air Controller (Airborne) (FAC(A)). Also known as Fast FACs, these F/A-18Ds, A-10s, and even F-16s employed as “killer scouts” expedited the location of targets and reduced the amount of time that the attack aircraft had to spend in the target area.³⁶ This function was particularly valuable during times of inclement weather and when visibility was reduced; without this capability, aircraft with small fuel loads such as the Harrier and the forward based F-16s would have been much less effective. Joint Forces Command in Riyadh assessed that the killer scouts increased the effectiveness of the attack force three to four fold.³⁷ FAC(A) employment demonstrated another low cost method of achieving higher sortie rates and overall attack force efficiency through existing conventional technology.

STOVL aircraft have the advantage of operating at reduced capacity from damaged airfields when other aircraft cannot operate at all. This flexibility holds the promise of providing effective sorties during the worst of times in combat. But, various methods are within reach that would allow all TacAir platforms to conduct operations in adverse conditions.

³⁵ William F. Andrews, MAJ, USAF, *Airpower Against an Army, Challenge and Response in CENTAF's Duel with the Republican Guard*, (Maxwell Air Force Base, AL: USAF Air University Press, February 1998), 50.

³⁶ Andrews, 51.

³⁷ Andrews, 52.

SURVIVABILITY

The combat survivability of a given aircraft is subject to many variables, including its thermal and radar reflective properties, handling characteristics, onboard threat countermeasures, and the capability of enemy anti-air technology. The vulnerability of an aircraft, however, is not restricted to the airborne regime. By striking an airfield, the enemy may deny takeoff and landing capability, thereby rendering the aircraft useless. Also, by attacking critical storage points or supply routes, the enemy may deny access to the necessary fuel and ordnance for aviation operations. Therefore, when discussing STOVL as a concept, one must consider not only the survivability of the aircraft, but also the survivability of the airbase from which it operates.

Aircraft Survivability: The Harrier program has demonstrated many difficulties in aircraft survivability. Its combat and peacetime attrition rate is several times greater than that of conventional and carrier based aircraft that share a similar mission.³⁸ If significant technological improvements are made, this problem can be isolated to the Harrier and will not necessarily be a malady common to STOVL aircraft in general.

In combat, the Harrier is particularly vulnerable to infrared missile attack because of the location and heat signature of its direct lift nozzles. Located in the hot spot near the nozzle area are the hydraulics, the fuel, the wing, the engine, the controls, everything vital to the survival of the aircraft.³⁹ Once hit, the single engine design renders survival of the aircraft virtually impossible. Of the three NATO jets shot down over Bosnia, all three (Harrier, F-16, and Mirage 2000) were of single engine design.⁴⁰ During Desert Storm, Iraqi air defenses destroyed five F-

³⁸ Harrier Review Panel, *HaRP First Annual Report (1997)*, HQMC.MIL/HARP, URL: <www.hqmc.mil/harp.nsf/>, accessed 12 October 2000, 3. Cited hereafter as HaRP First Annual Report.

³⁹ "Marine Air: There When Needed," 126.

⁴⁰ Hancock, 9.

16s and four AV-8Bs.⁴¹ Every Harrier hit by a missile resulted in the loss of the aircraft. In contrast, all five of the twin-engine Hornets hit by SAMs during the Gulf War flew back home with battle damage.⁴² The combat survivability record of the Harrier is almost completely attributable to its single-engine design.

The relatively poor peacetime survivability record of the Harrier may be attributed not only to its single engine design, but also to the complexity of the direct lift V/STOL system and the difficulty of handling the aircraft as it transitions to or from the vertical flight regime. Since 1991, the Harrier Class A mishap rate has been approximately 400% of the U.S. Marine Corps F/A-18 rate for the same period.⁴³ “The discriminating issue is that regardless of cause, when the engine fails, the Harrier pilot must always eject, while 90(+)% of the time, the Hornet pilot returns home for an uneventful single engine landing.”⁴⁴

In addition to the problems caused by having a single engine design, the Harrier also suffers from the difficulties of V/STOL operations. While the HaRP states that the V/STOL penalty is not a major accident rate driver (approximately one accident caused by V/STOL pilot error per 100,000 flight hours) and appears to be under control, the statistics suggest just the opposite. V/STOL pilot error alone accounts for an accident rate equal to nearly half of the total accident rate of the USMC F/A-18 from all causes (2.47 per 100,000 flight hours). Takeoff and landing Class A mishaps in the Harrier occur at a rate that is over 450 percent of the Hornet rate in the same flight regime (2.35 per 100,000 hours versus 0.52 per 100,000 hours).⁴⁵

⁴¹ LeRoy D. Stearns, *U.S. Marines in the Persian Gulf, 1990-1991, The 3d Marine Aircraft Wing in Desert Shield and Desert Storm*, (Washington, D.C., Headquarters, U.S. Marine Corps, 1999), 161.

⁴² Hancock, 9.

⁴³ HaRP First Annual Report, 3. A Class A mishap is one that results in permanent injury or death, or causes a minimum of \$1 million damage to the aircraft.

⁴⁴ HaRP First Annual Report, 3.1.

⁴⁵ HaRP First Annual Report, 3.2.1.

The STOVL JSF program designers promise to correct the survivability problems of Harrier through improved technology.⁴⁶ The fact remains, however, that the JSF is a single engine aircraft, and the STOVL variant will be significantly more complex in design and operation than its conventional and carrier counterparts.⁴⁷ Aircraft reliability, maintainability and survivability could remain a significant hurdle for future TacAir STOVL platforms to overcome.

Airbase Survivability: Dispersal of airfields and FARPS can complicate the targeting problem for the enemy. Also, by having a larger number of bases, an attack on a dispersed site would have less impact on the total Air Combat Element than would an attack on a main operating base housing all the aviation assets. The irony is that by dispersing our assets, we complicate our force protection problem and at the same time create a logistical problem of enormous magnitude which itself requires protection. This problem is not unique to STOVL, but is a universal risk of operating aircraft in a hostile environment.

One major advantage of a main operating base is that its centralized location and distance from the battlefield lends itself to protection by assets such as the Patriot missile system. Likewise, the Carrier Battle Group has numerous and effective anti-aircraft assets that protect it from attack. Since the disappearance of the Hawk missile system, the Marine Corps no longer owns a radar guided air defense missile and is therefore reliant on the meager Stinger system for protection against air attack. The Stinger is not only limited by its cueing and tracking system, but its limited range capability makes it a weapon of revenge. The only target close enough to

⁴⁶ Herman, *Marine Corps Gazette*, May 1999, 50.

⁴⁷ Robert R. Reed, *Summary of Reliability and Maintainability Research Relating to the Joint Strike Fighter Program*, Study. (Monterey, CA: Naval Post Graduate School, October 1998), 5.

hit with a Stinger missile is one that holds Marines at risk within the effective range of air to ground weapons.

Dispersed airfields could be even more vulnerable to ground attack than they are to air attack. The threat of saboteurs, special forces units, and terrorist or guerrilla groups demands that local security be provided for every site that is established. Some of these forces will be supplied by the aviation units, but the majority will have to come from other sources such as the Military Police, or the combat units of the Ground Combat Element.

Enemy aircraft and ground forces are not the only threat to dispersed bases. Nothing organic to the Marine Corps can keep dispersed airfields safe from attacks by surface to surface missiles such as the SCUD. It takes the advanced missile technology of the Patriot to accomplish that mission, and those assets will most likely be located only at main operating bases.

Another area of vulnerability is the supply line. To keep dispersed sites sufficiently supplied with fuel and ordnance, aviation units must either create an unwieldy logistics train (the Saudi government provided forty-five 8,000 gallon tankers to fuel Hornets, Harriers and other aircraft located at King Abdul Azziz Naval Air Station and Jubayl Naval Air Facility⁴⁸), or they must fly resupply missions at a rate comparable to that of the TacAir sorties. The maximum capacity of a CH-53E carrying both internal and external fuel bladders, is approximately 48,000 pounds of jet fuel. This is enough to refuel three STOVL JSF aircraft.⁴⁹ If more ordnance is required, that takes another helicopter sortie. These extra helicopter, or presumably Osprey, sorties are themselves vulnerable to attack, as are ground logistics trains.

⁴⁸ Hancock, 48.

⁴⁹ Hancock, 50.

Survivability is not a problem unique to the STOVL program. The advantages of using dispersed sites by any type of aircraft must be carefully weighed against the vulnerabilities. Single engine survivability is also not unique to STOVL. Many aircraft, including the conventional versions of the JSF, are single engine and therefore must deal with the vulnerabilities presented by such a design. Technology may overcome the aircraft survivability problem, but the protection of dispersed sites and their logistical support structure could remain an obstacle for a very long time. It may be that the protection afforded to large bases and carriers by advanced air defense systems and distance from the enemy far outweighs the advantages of dispersed operating sites.

EXPEDITIONARY MANEUVER WARFARE

If flexibility is the strong point of the STOVL program, survivability is its weak point. The Marine Warfighting concept of Operational Maneuver From the Sea (OMFTS) acknowledges the difficulties presented by forward basing and suggests that operating from Naval shipping is a promising alternative.⁵⁰ STOVL TacAir provides a unique capability to operate from amphibious shipping and has fulfilled its role within the Marine Corps, but at significant cost in terms of safety and combat performance.

The AV8-B program was created as a means to generate more combat power for the Marine Air Ground Team, but in wartime, it under-performed the sortie rate of its contemporaries. During Desert Storm, the Harrier posted an average of 38.8 total sorties per aircraft, compared to 46.4 for Hornets, 50.5 for the F-15, 53.7 for the F-16, and 59.4 for the A-10.⁵¹ The Harrier Review Panel has determined that, “despite a substantial level of effort on the

⁵⁰ *United States Marine Corps Warfighting Concepts for the 21st Century*, IV-16,17.

⁵¹ Title V Report, *Conduct of the Persian Gulf War: Final Report to Congress*, (Washington, D.C., April, 1992), Appendix T, Performance of Selected Weapons Systems. The sortie count is based on total number of sorties flown divided by number of aircraft in theater and does not differentiate ground attack sorties from other mission types.

part of the Marine Corps, the aircraft still lacks an appropriate synergy of attributes that would make it truly relevant in today's operational environment."⁵² Many options exist within the capabilities of America's conventional aviation inventory that can deliver a higher sortie rate and more total ordnance than the Harrier. With the engineering limitations of STOVL design, many believe that the Marine JSF will also under-perform its conventional peers.

⁵² HaRP First Annual Report, 3.4.1.

STOVL JSF ATTEMPTS TO ANSWER THE HaRP

I feel a sense of measured urgency in regard to reducing the potential for near-term loss of Marines and aircraft. For this reason, the panel will focus its initial efforts on identifying substantive means to significantly reduce the AV-8B mishap rate and enhance community confidence in their aircraft. ... Appropriate long haul actions are essential to ensuring that the Harrier can fulfill its mission requirements until the last squadron is replaced by the Joint Strike Fighter.

*C. C. Krulak
HaRP Charter, 7 Nov 1997*

The more you do what you do, the more you get what you got.

A member of the HaRP

It has been well established that the Marine Corps Harrier program suffers many problems not associated with other aviation communities. By convening the Harrier Review Panel in 1997, Commandant of the Marine Corps General C. C. Krulak began a formal quest to resolve these problems in the hopes of saving lives, resources and materiel. The goal, as stated by the Commandant, was to ensure that the Harrier could fulfill its mission until it could be replaced by the JSF.⁵³ During development of the JSF, Boeing and Lockheed Martin have attempted to create a STOVL aircraft that solved the problems identified by the HaRP, specifically, that the Harrier is “a single engine airplane, which is challenging to fly, difficult to maintain, and which, because of its relatively low priority within DoN, lags other aircraft in warfighting capabilities.”⁵⁴ The Boeing Company’s Manager of Business Development for the JSF program, Theodore Herman, published an article in *Proceedings* that outlines the ways in which the two JSF STOVL programs intend to solve the Harrier’s Problems. This article must

⁵³ Commandant of the Marine Corps, message to Deputy Chief of Staff for Aviation, subject: “Establishment of a USMC Harrier Review Panel,” 3700 APP4, 7 November 1997.

⁵⁴ HaRP First Annual Report, 3.

be viewed with skepticism for two reasons. First, the source, while possibly the most reliable for factual data on the subject, is biased toward its product and has a vested interest in its success. Second, it is based on modeling and simulation data and represents what the contractors expect to achieve from their creations. Reviewing the design promises and “proven capabilities” of the previous STOVL program reveals the potential inaccuracies of this type of speculation. For example, in 1979, a briefing to the Defense Science Board stated that the Harrier was a “small, simple aircraft” with an “outstanding safety record.”⁵⁵ The Harrier later proved to be a very complex aircraft, suffering an accident rate four times that of its Marine TacAir counterparts.⁵⁶ With this in mind, the JSF’s answers to the HaRP’s findings will be compared to other studies on the performance of JSF STOVL.

SINGLE ENGINE DESIGN

The first issue under consideration is the single engine design. The HaRP found that the core engine reliability for the AV-8B has been substantially better than that of the F/A-18, and that on any given flight there is about an equal chance of a propulsion system failure in either airplane. With the Harrier, however, the cause is likely to be maintenance related, whereas for the Hornet it is most commonly a materiel failure. “The bottom line is that the probability that a maintenance mistake, pilot error, or materiel failure will result in catastrophe is much higher in an AV-8B squadron than in an F/A-18 squadron.”⁵⁷ Given the safety and survivability records of single-engine aircraft, one would expect the next generation of advanced strike fighters to capitalize on the obvious advantages of a dual-engine design. This is not the case, however, as the Marine Corps’ version of the JSF is a single-engine STOVL aircraft, “a combination that

⁵⁵ Defense Science Board, 1979, 67-70.

⁵⁶ HaRP First Annual Report, 3.

⁵⁷ HaRP First Annual Report, 3.1.

many would dub the worst possible for survivability and safety in a tactical aircraft.”⁵⁸

Propulsion system failures within the AV-8B have resulted in a Class A mishap rate of four aircraft per 100,000 flight hours. The point that the HaRP makes is that, while the Hornet has had over fifty percent more propulsion system failures or shutdowns, the related Class A mishap rate is only 0.35 per 100,000 flight hours, due to the existence of a second engine.⁵⁹

From a design perspective, a single engine aircraft not only costs less, but is also lighter than a twin engine aircraft. Additionally, the difficulty involved in producing a STOVL lift design that incorporates two engines is compounded by the thrust-to-weight ratio required for vertical landings. Therefore, the design teams have determined that “a powerful, reliable, and lightweight single-engine design is the best and simplest alternative to achieve the thrust margin necessary for controllability and weapons-bringback capability for a vertical landing aboard ship.”⁶⁰ Their answer to increasing the survivability of the single-engine JSF is to focus on the overall reliability of the engine itself.

“Today’s single-engine airplanes can attain levels of safety and reliability virtually equal to those of twin-engine aircraft. Leveraging the great strides in design, metallurgy, and maintainability that have been made in recent years, the JSF engine will be far more reliable, long-lived and more powerful than today’s engines.”⁶¹

To date, no evidence exists to demonstrate that an aircraft equipped with a single JSF engine will be more safe and survivable than a twin-engine aircraft using similar engine technology. In support of the single-engine argument, the Herman article cites the performance of the F-16, America’s only other single engine TacAir platform. By careful management of its

⁵⁸ Herman, *Proceedings*, April 2000, 72.

⁵⁹ HaRP First Annual Report, 3.1. It should be noted that many of the F/A-18 NATOPS emergency procedures call for precautionary engine shutdown to prevent further damage to the aircraft. While a Hornet pilot may shut down an engine for a variety of reasons, the pilot of a single-engine aircraft will probably keep a troubled engine online until catastrophic failure occurs.

⁶⁰ Herman, *Proceedings*, April 2000, 73.

⁶¹ Herman, *Proceedings*, April 2000, 73.

maintenance and maintenance training programs, and heavy investment in component improvement, the F-16 community has reduced its mishap rate dramatically. While the \$63 million dollar USAF F-100/110 engine improvement program has improved the F-16's propulsion related Class A mishap rate, it is still over three times as high as the combined rate of the Navy and Marine Corps F/A-18s, which are subject to the additional handicap of shipboard maintenance and supply operations.⁶²

Some technological advancements hold great promise in increasing the reliability of the JSF over that of its single engine predecessors. Fewer parts, easier component replacement, and a prognostic health management system are all improvements over current engine designs.⁶³ The issue brought up by the HaRP, however was the lack of engine redundancy that two engine aircraft enjoy. When an engine fails, whether due to a maintenance or materiel problem or to battle damage, a single engine pilot usually ejects, while a twin-engine pilot can usually return home for a safe landing. Despite all of this, and because of the cost and difficulties involved with engineering a twin engine STOVL aircraft, the designers of the JSF have, in effect, told us just to not worry about it.

CHALLENGING TO FLY...

The HaRP discounts the "V/STOL penalty" as a cause of pilot error related Class A mishaps. This is because the V/STOL regime is such a minute part of the total Harrier flying time, and because V/STOL related pilot error mishaps account for only ten percent of the total cumulative Class A mishap rate.⁶⁴ The Herman article states that "[t]he perception that the Harrier spends a lot of time in the STOVL environment and therefore pays a mishap penalty for

⁶² HaRP First Annual Report, 3.1.1. Component Improvement Program funding figures include Prime Contractor funding only and do not include DoN and USAF infrastructure costs.

⁶³ Herman, *Proceedings*, April 2000, 74.

⁶⁴ HaRP First Annual Report, 3.2.1.

such exposure is not supported by facts.”⁶⁵ However, the fact that the Harrier spends such a small amount of time in the STOVL flight regime is the reason that the number of STOVL related mishaps is significant. The Class A mishap rate attributed only to V/STOL pilot error is twice that of Marine Corps F/A-18s in all takeoff and landing related causes. All V/STOL related causes contribute to a rate that is three times that of Marine Corps F/18s in all takeoff and landing related causes, and still more AV-8B accidents occur in this flight regime that are not V/STOL related.⁶⁶ The perception that the Harrier spends a lot of time in the STOVL environment is not supported by fact; the perception that the Harrier pays a mishap penalty for such exposure is certainly well supported by facts.

While the HaRP discounted the V/STOL flight regime as a major mishap rate driver, it recognized pilot error caused by inexperience as a major causal factor of Harrier accidents.

“Pilots with 400 hours or less in type account for approximately 70% of the Class A pilot error accidents. Pilots with less than 200 hours in type cause 40% of the Class A pilot error mishaps. This represents a pilot error rate that is twice what would be expected by their representation in the pilot population and by their contribution to community flying hours.”⁶⁷

The difficulty in flying Harriers has become a cascading casualty for the Marine Corps. Because of the poor view of the Harrier program within the aviation community, pilots with the best Naval Air Training Command scores most often request assignment to the F/A-18.⁶⁸ Still, minimum selection standards for the AV-8B pipeline remain the highest of any aviation platform. Once selected into the Harrier community, these new pilots undergo training at the Fleet Replacement Squadron (FRS). The HaRP found that the FRS has been under-resourced, and that the combined flight and simulator training syllabus has at times been up to 45 percent

⁶⁵ Herman, *Proceedings*, April 2000, 74.

⁶⁶ HaRP First Annual Report, 3.2.1.

⁶⁷ HaRP First Annual Report, 3.2.2.

⁶⁸ HaRP First Annual Report, 3.2.2.

smaller than that of comparative TacAir aircraft such as the Hornet and F-16.⁶⁹ Once in a fleet squadron, a Harrier pilot can expect to fly only 63 to 66 percent of the average flight hours flown by Hornet pilots. This is due to the poor operational availability of Harriers in the FMF. “The underlying causes of poor operational availability are very broad—insufficient resources (publications, parts, support equipment (IMRL)), recurring materiel problems, poor reliability and maintainability, and inadequate manning and experience levels. Lack of aircraft to schedule and fly was seen as the major degrader.”⁷⁰ The challenge of flying the Harrier can be overcome by training and experience, but the Department of the Navy (N88) has thus far failed to provide adequate resources to provide pilots with a level of experience on par with their conventional TacAir counterparts.

The STOVL JSF, like any TacAir platform, will be a challenge to fly. But by focusing on reduced pilot task loading and by utilizing an integrated flight propulsion and control system the JSF designers hope to develop an aircraft that is far simpler to operate than the Harrier. “This is not to say that all STOVL challenges will be eliminated... task loading for the JSF pilot will be centered more on commanding the airplane to go where he wants it, not in making multiple manual control system inputs to effect a desired response.”⁷¹ Many Harrier mishaps have occurred as a result of pilot error that was exacerbated by high task loading, and usually because of misapplication of engine or flight controls. By incorporating a hands-on-throttle-and-stick (HOTAS) system for flight, engine, and nozzle controls, the pilot workload can be appreciably decreased. Additionally, an integrated flight propulsion and control system will prevent the pilot from inadvertently entering a flight regime that will result in the loss of control

⁶⁹ HaRP First Annual Report, 3.2.3.

⁷⁰ HaRP First Annual Report, 3.2.4.

⁷¹ Herman, *Proceedings*, April 2000, 75.

of the aircraft.⁷² Technological advances that make the JSF easier to fly will make the pilot experience level less of a factor in future mishaps.

The plan for the JSF will include common training facilities and programs for pilots from all services. The main flying and tactics syllabus for all JSF variants will be largely identical. Therefore, one would expect the system to produce pilots of uniform quality for all TacAir squadrons, thus alleviating the training disparity that currently exists among members of the Harrier community. Keep in mind, however, that the STOVL JSF will still be unique to the Marine Corps, and as a result will require specialized training at increased cost. Because the STOVL program is not shared by the other services, the possibility still exists that the resources devoted to it will lag the conventional land and carrier based JSF versions. The JSF, and the STOVL JSF in particular, will be challenging to fly. Like the Harrier, the STOVL JSF will require well trained pilots selected from the top tier of the training command. If the STOVL JSF does not prove to be easily maintained, the training challenge may be magnified by lower operational availability of aircraft within the FMF.

MAINTAINABILITY

A major finding of the HaRP was that Harrier maintenance errors result in mishap rates that exceed the USMC F/A-18 maintenance error rates by “more than an order of magnitude.”⁷³ The majority of maintenance errors occurred because of a lack of adequately trained and experienced maintainers that are capable of proper care of a very complex system. The average maintenance experience of I-level maintainers (the lowest maintenance level authorized to repair engines) within the Hornet community is 12 years. Within the Harrier community that figure is reduced to five years. This problem is compounded by the complexity of the Harrier design.

⁷² Herman, *Proceedings*, April 2000, 75.

⁷³ HaRP First Annual Report, 3.3.

While a Hornet maintenance crew can remove and replace an engine in ten man-hours, completing the same task on a Harrier requires 550 man-hours.⁷⁴

It is hard to imagine that the JSF could be more difficult to maintain than the Harrier. The new aircraft is designed for ease of manufacture and maintainability, using fewer parts that are of a higher quality than were previously available. Better diagnostics systems and graceful degradation to backup systems are designed to increase reliability and relieve much of the maintenance burden of current aircraft systems. “In both companies’ JSF proposals, the engine is designed to be maintained primarily on the airplane, and to be removable in 2.5 hours or less using only four people and a minimum of tools.”⁷⁵ These refinements hold great promise in alleviating the difficulties experienced by the Harrier program in the realm of maintainability. None of these design promises, however, address the relative complexity of the STOVL version of the JSF as compared to the conventional land and carrier based versions.

A memorandum from Secretary of Defense William Perry, dated 29 June 1994, makes it impossible to require contractors to supply reliability and maintainability information on systems under development.⁷⁶ Since actual design specifications of the two JSF versions are not releasable due to classification or sensitivity, various studies conducted by the Naval Post Graduate School, the Center for Naval Analysis, and the RAND Corporation use notional aircraft based on computer simulation models as study subjects. These notional aircraft, “[a]lthough not identical to any contractor configuration, [are] representative of them, and the analysis results track well with the contractor results.”⁷⁷ The studies are designed to project, among other things,

⁷⁴ HaRP First Annual Report, 3.3.4. Table 6.

⁷⁵ Herman, *Proceedings*, April 2000, 76.

⁷⁶ Robert R. Reed, *Summary of Reliability and Maintainability Research Relating to the Joint Strike Fighter Program* (Monterey, CA: Naval Post Graduate School, October 1998), 3.

⁷⁷ Daniel P. Raymer, *Next-Generation Attack Fighter: Design Tradeoffs and Notional System Concepts* (Santa Monica, CA: RAND Corp., 1996), 2.

reliability and maintainability of the aircraft and its systems, and the design tradeoffs among the three JSF versions (STOVL, conventional land based (CTOL), and conventional carrier based (CVTOL)).

The basis for a reliability and maintainability estimate for the JSF will center on three things. First, the relative complexity of the system is based on hardware component count (ducts, nozzles, etc.) and control features (actuation and electronics).⁷⁸ Second, component availability directly affects the number of operational sorties produced by a particular aircraft.⁷⁹ Finally, mean time to Failure (MTTF) and mean time to replacement (MTTR) of component parts will impact the type and frequency of maintenance required by a specific JSF variant.⁸⁰

While the JSF designers strive to reduce the complexity of the aircraft systems, the fact remains that the STOVL versions produced by both contractors will require a larger number of parts and actuations, and will by nature be more difficult to maintain than either corresponding CTOL or CVTOL version. This fact is supported by studies from Naval Post Graduate School which compare projected component designs for the STOVL JSF to current Harrier design and projected JSF CVTOL design.

“A case has been presented showing that the STOVL versions are less reliable and less maintainable than the CVTOL version for the Navy’s next fighter. The first indication is in the form of counts of components.”

	Direct Lift	Lift Fan	Other (Harrier and JSF CVTOL)
Actuation Features	8	12	2 (Pegasus)
Control Actuators	14	17	7 (Pegasus)
Component Counts	42	44	19 (CVTOL)

(Figure 2)⁸¹

⁷⁸ Reed, 8.

⁷⁹ Reed, 15.

⁸⁰ Reed, 15.

⁸¹ Reed, 15. For actuation features, exclude the Reaction Control System and fuel metering required for STOVL flight. For component counts, exclude avionics. Pegasus is the Rolls Royce produced engine of the Harrier.

In addition to component counts that are much higher than conventional aircraft, the two STOVL designs (Boeing's Direct Lift (DL) and Lockheed Martin's Lift Fan (LF)) face unique engineering obstacles caused by the complexity of the STOVL components.

"Perhaps the most controversial components are the clutch and gear box systems, and the block and turn devices internal to the engine. The clutch and gear box systems needed in the LF concept represent unusual engineering challenges and considerable doubt has been expressed as to the success of this part. The offsetting feature of this is that the LF concept is potentially more efficient than the DL concept. It is important for both STOVL types to have high MTTF values for the block & turn and related devices. Repair of these call for the removal of the engine, a high repair time task."⁸²

The relative complexity of the STOVL designs based on hardware component count and control features indicate a potential reliability and maintainability level below that of the CTOL and CVTOL variants. Remember, the problem with the AV-8B was not its failure to perform better than the AV-8A, rather its failure to perform on par with its TacAir contemporaries. Although the STOVL JSF is projected to be a vast improvement over the Harrier, it still faces the very real possibility of falling into that same trap.

The second aspect of maintainability is parts availability. An Engine Working Group survey conducted by the HaRP revealed that Harrier engine maintainers frequently experience parts shortages from inadequate in-shop Pre-Expended Bins and insufficient supply allowances. In fact, an alarming number of these maintainers reported that they have re-used parts that were meant to be thrown away.⁸³ The prime cause for this is funding, mainly due to the relatively low priority of the Harrier in Naval Aviation. Because of funding, the parts supply is slow, but slower still are improvements to aircraft components. While it is common for Naval aircraft to spend an inordinate amount of time awaiting Engineering Change Proposals (ECPs) that will make their aircraft better and safer, the impact on STOVL aircraft can be debilitating.

⁸² Reed, 19, 20.

⁸³ HaRP First Annual Report, 3.3.

“It is sobering to see how many AV-8B ECPs that are still ‘in-process’ have come from Class A mishaps. Equally disturbing is the number of times that an identified material deficiency has caused additional mishaps before it was eventually corrected.”⁸⁴

Parts availability is not only a safety issue, though that should be sufficient, but it is also an issue that affects sortie generation. STOVL and CVTOL parts do not have the same availabilities and, therefore, the number of aircraft that are unavailable for the flight schedule because they are awaiting parts will also be different. CVTOL aircraft availability is historically 80 percent, while STOVL availability is only 63 percent. “Thus one might build a case that fewer sorties may be generated using STOVL aircraft rather than CVTOL. This is a far cry from the 23% STOVL advantage claimed by [the Center for Naval Analysis].”⁸⁵ Unless the Air Force and Navy buy into the STOVL JSF, it could be doomed to the same low priority as the Harrier.

The final point of the maintainability analysis is based on the mean times to failure and replacement of STOVL and CVTOL components. In the Naval Post Graduate School studies, critical component MTTF values indicated 27.3 hours for CVTOL versus 11 hours for the STOVL aircraft. “It follows that the STOVL goes into the repair shop about 2.5 times as often as the CVTOL.”⁸⁶ The relative complexity of the STOVL design as compared to the conventional designs leaves little reason to doubt this test data.

The Herman article clearly outlines the advancement in basic engine reliability for the STOVL JSF. What is not so obvious is the fact that the provided data only refers to components common to all JSF models.

“Adopting a common engine for all services provides a broader-based and higher level of experience and corporate knowledge. Better spare parts availability, more attention to continuous engine improvements and upgrades, and true inter-service operability are just some of the advantages. In addition, costs to each of the services for modifications,

⁸⁴ HaRP First Annual Report, 3.5.3.

⁸⁵ Reed, 15.

⁸⁶ Reed, 15.

continuing development, and upgrades will be considerably less than if the engine were service-specific.”⁸⁷

While all of this may be true, the fact remains that everything relating to the STOVL capability of the Marine Corps version of the JSF is service specific. The Marine Corps is the one service that cannot afford to have a more complex aircraft. The specificity of the STOVL components presents a great potential for the JSF to continue in the tradition of low priority hardships that have become the legacy of the Harrier program.

LOW PRIORITY

“The priority and warfighting relevance arguments are subtler: part reality, part perception; they nonetheless have indirect but pervasive ties to safety risk. They reveal themselves in consistently low DoN funding priorities, as well as consistently low regard for the platform by the Joint and Unified Commanders.... The predictable results are support deficiencies, morale erosion and, in recent years, one of the weaker manpower retention records in Marine Corps Aviation. This ‘vicious cycle’ presents an unhealthy backdrop for a system that is already burdened with a high incidence of human factor mishaps.”⁸⁸

The uniqueness of the STOVL JSF bears a bad omen to its priority within the Department of the Navy and the Department of Defense. The goals of the JSF program were a reduction in the development, production, and lifetime costs of America’s strike fighter platforms. Commonality was the single most important factor that would bring this reduced cost to fruition. The Herman article addresses this issue by sidestepping the uniqueness of the STOVL program:

“Since the JSF is a multi-service effort, fielding 60% to 90% commonality among airframes (depending on the manufacturer), and 100% commonality among the core engines, the resulting synergy guarantees the STOVL version will not be an orphan in the U.S. Department of the Navy.”⁸⁹

In truth, the resulting synergy of airframe and engine commonality presents no guarantees in terms of STOVL components and performance. Herman goes on to say that, with

⁸⁷ Herman, *Proceedings*, April 2000, 76.

⁸⁸ HaRP First Annual Report, 3.

⁸⁹ Herman, *Proceedings*, April 2000, 75.

the JSF, the tactical fixed-wing community of the Marine Corps will enjoy the type of multi-service support that the F/A-18 enjoys today.⁹⁰ If the Naval Post Graduate School JSF reliability studies hold any merit at all, the STOVL JSF – “the most technically complex of the three JSF variants” – could suffer from difficulties that are in no way common to the other services.⁹¹ And once we become an all STOVL force, the Marines will no longer have a healthy, well-supported TacAir platform that is capable of taking up slack for an orphan STOVL program.

WARFIGHTING CAPABILITIES

The issue of lagging warfighting capabilities was not even addressed by the Herman article. Design restrictions caused by the requirement for vertical flight cause the STOVL JSF to lag the other JSF versions in internal payload capacity and combat range.⁹² A 1999 report in the Marine Corps Gazette on the status of the JSF program states the reality of the STOVL penalty:

“Boeing’s recent JSF redesign, while reducing overall weight of the aircraft and improving vertical landing payload, still doesn’t quite measure up to the amount of fuel and weaponry the Marine Corps wants on its STOVL variant. Lockheed Martin, with the added weight of its lift-fan design (4,000 additional pounds), also continues to look for ways to expand the range and weaponry of its STOVL aircraft.”⁹³

Until recently, the JSF designs did not measure up to the amount of fuel and weaponry that the Marine Corps wants on its STOVL variant. Consider also that the Marine Corps asked for an internal payload that is only one half the capacity of the other services’ JSF versions. The STOVL JSF will have to generate twice as many sorties in order to deliver the same amount of internally carried ordnance as the CTOL and CVTOL variants (thus retaining its low observability characteristics). While the internal payload is only a fraction of the total payload

⁹⁰ Herman, *Proceedings*, April 2000, 75.

⁹¹ R. M. Schmitt, “Joint Strike Fighter – You Say You Want a Revolution...” *Marine Corps Gazette*, May 1999, 40.

⁹² External payload capacity of the STOVL JSF is comparable to that of the conventional variants. For some ground attack missions, all JSF variants will carry external stores.

⁹³ Schmitt, 42.

capability of the aircraft, carrying external stores compromises the combat survivability of the single-engine JSF's low observable design. Additionally, one must look no farther than an Energy/Maneuverability diagram to see that the extra 4,000 pounds of lift fan will have a detrimental effect on the turn performance and energy addition capability of the Lockheed Martin design.

The STOVL JSF, by design, lags its contemporaries in real, measurable warfighting capability expressed in weapons load, combat radius and flight characteristics. And still more factors emerge:

“Another concern plaguing both manufacturers centers around the environmental impact of the STOVL designs. The JSF STOVL variant is hotter and noisier than the AV-8B, both considerations that could substantially impact shipboard and airfield operations.”⁹⁴

Shipboard operations are the mainstay of the Marine Corps' Operational Maneuver from the Sea concept.⁹⁵ If the STOVL JSF proves impractical for shipboard operations then the program is likely to consume funds until the problem is alleviated.

HaRP VS. STOVL JSF

In the final analysis, does the STOVL JSF program, as it exists today, answer all of the HaRP's questions as it claims?

- | | | |
|---------------------------|--------|---|
| 1. Single Engine: | No. | JSF is a single engine design. |
| 2. Challenging to fly: | Maybe. | Advances in flight control systems will improve the flyability of the aircraft significantly over the Harrier, but it will still be considerably more challenging than the conventional JSF variants. |
| 3. Difficult to maintain: | No | Complexity of design relative to the other JSF variants provides a forecast of maintenance difficulties not shared by the other services. |

⁹⁴ Schmitt, 42.

⁹⁵ *United States Marine Corps Warfighting Concepts for the 21st Century*, IV-12.

- | | |
|--------------------------------|---|
| 4. Relatively low priority: No | Unless the U.S. Navy buys STOVL, the uniqueness of STOVL could overshadow the commonality of the JSF program. |
| 5. Lagging Capabilities: No | By design, the STOVL JSF lags the other variants in combat radius due to weight and fuel capacity, and carries half the internal payload of the conventional designs. |

The issue with the Harrier program was not whether the Harrier II was vastly improved over the AV-8A, but rather how it performed in comparison to its conventional counterpart, the F/A-18. The evidence suggests that the performance of the STOVL JSF will be below par in comparison to the CTOL and CVTOL variants in the areas of affordability, maintainability, internal payload capacity, and combat radius. That is the reality of the STOVL penalty. The question is how much is the Marine Corps willing to pay for STOVL, and what are the alternatives?

ALTERNATIVES TO STOVL:

THE BENEFITS WITHOUT THE PENALTIES

I am tempted indeed to declare dogmatically that whatever doctrine the armed forces are working on now, they have got it wrong. I am also tempted to declare that it does not matter that they have got it wrong. What does matter is their capacity to get it right quickly when the moment arrives.

Sir Michael Howard

As the Defense Science Board proclaimed, many missions exist that could benefit from the existence of V/STOL aircraft. Most of these missions are “susceptible to various other solutions,” and none are so “uniquely improved by V/STOL as to absolutely demand its adoption.”⁹⁶ That was 1979, when the Hornet was still the F-17X. Twenty-two years later, the needs that the Marine Corps intended to fulfill with the Harrier are still valid. The original objectives of the V/STOL program (flexible basing, high sortie rates, and survivability) provide a structure through which alternative solutions may be investigated.

FLEXIBLE BASING

The issue of flexible basing is the principle reason that STOVL exists. The number of established airfields that have 2,000 feet of runway or more is much larger than those with 8,000 feet or more. STOVL not only enables the use of these runways, but also provides the ability to operate from roads, FARPs and from the decks of amphibious shipping. So, are there other solutions to this requirement?

Close examination of the worldwide airfield availability chart provided in the May 1999 *Marine Corps Gazette* shows approximately 2,600 airfields with 2,000 feet or more of usable runway. The worldwide availability of airfields with 3,000 feet or more of usable runway is

⁹⁶ Defense Science Board, 1979, 13.

approximately 1,400.⁹⁷ Comparing this data to the short takeoff and landing capability of existing non-STOVL aircraft reveals a great amount of flexibility in our existing fleet. The F-16, F-18 and F-15 are all capable of taking off at combat weight with less than 2700 feet of runway.⁹⁸ These figures suggest that an incredible amount of basing options are readily available to existing non-STOVL aircraft, at no additional development cost, with no STOVL penalties. By using portable arresting gear, the landing capability of these aircraft could easily be reduced, thereby opening up the possibility of using runways as short as 3,000 feet or even less.

Opponents state that the difficulty involved in installing arresting gear is prohibitive. A fighting force capable of installing over 1,750,000 square feet of AM-2 matting on a bed of 200,000 cubic yards of fill dirt in order to improve a FARP during Desert Storm is certainly capable of installing a set of arresting gear on an existing runway.⁹⁹ Each Marine Air Wing has the assets available to construct two EAF 2000 airfields, which consist of a 3,800-foot by 72-foot runway, various taxiways, and parking areas. The entire airfield can be assembled in 18 to 30 days, and can support 75 tactical aircraft or assault support helicopters and three C-130s.¹⁰⁰ This too is a capability that already exists within the Marine Corps inventory, and requires none of the development and maintenance costs of STOVL.

STOVL aircraft do not have a monopoly on operating from roadways either. Conventional aircraft of various types have demonstrated the capability to perform this feat, and in fact the air forces of the Scandinavian countries have operated conventional aircraft from highway strips in all sorts of weather for years.¹⁰¹ These countries, and Korea as well, even have

⁹⁷Herman, *Marine Corps Gazette*, May 1999, 50.

⁹⁸ Source: Combat Flight Planning Software. Data calculated using typical load-outs for Desert Storm Air-to-Ground sorties, full internal fuel for all aircraft, standard day at sea-level.

⁹⁹ Hancock, 44.

¹⁰⁰ *Expeditionary Airfields Information Paper*, Aviation Branch, Headquarters USMC (Washington, D.C.: Aviation Branch, HQMC, ASL-45, 8 August 1994), 1.

¹⁰¹ Stout, 47.

highway sections that are marked specifically for runway operations by their conventional aircraft.¹⁰²

Short runways and roads are not the exclusive domain of STOVL. Neither are FARP operations. The Desert Storm experience demonstrated that F-16s and F-18s utilized FARPs very effectively, and to an equal or greater degree of frequency than did the Harriers.¹⁰³ We tout STOVL as being a force multiplier because of its ability to operate from FARPs, roads and short runway environments. Just imagine the degree of force multiplication that could be achieved by installing a few sets of arresting gear and enabling all of our fixed wing assets to operate from austere sites.

STOVL enjoys many feasible, supportable basing options. Most, but not all, of these are currently within the capabilities of conventional TacAir. Without major modifications to naval vessels, conventional fixed-wing aircraft cannot operate from amphibious shipping. For various reasons, the Marine Corps will not rely on carrier based fixed-wing support to its MEU operations; and without fixed wing TacAir support, the MV-22 Osprey, which is the backbone of the OMFTS concept, is not supportable. What's more, the Navy will have nothing to do with suggestions to modify its L-class ships to accept the ski-jumps and arresting gear required to operate conventional aircraft from these vessels.¹⁰⁴

Just because the Navy does not support the concept of conventional fixed-wing operations aboard L-class shipping does not mean that such operations are not possible. Indeed, this type of fixed-wing employment is within the capabilities of our current equipment and technology.

¹⁰² Herman, *Marine Corps Gazette*, May 1999, 49.

¹⁰³ "Marine Air: There When Needed," *U.S. Naval Institute Proceedings*, November 1991, 126.

¹⁰⁴ LtCol Tim Dally, USMC, Aviation Requirements, Marine Corps Combat Development Command, interview by the author, 27 November 2000.

“A combination of jet assisted takeoff (JATO) rockets and ski-ramps, in concert with a light and simple set of arresting gear, and perhaps a simple angled deck, would enable the JSF to operate from the LHAs and LHDs.... The JSF, which is much lighter and will land much slower than behemoths such as the A-3 and the F-14 which the earlier gear were designed to handle, will not impose such severe design and material demands. All of this should come at a cost that is less than the cost in terms of dollars and poorer performance that the STOVL version of the JSF will levy on the Marine Corps.”¹⁰⁵

The feasibility of constructing an angled deck on existing shipping is beyond the scope of this discussion. Still, it has been noted as a point of irony that the world’s largest operator of STOVL aircraft does not have ramps on its amphibious ships.¹⁰⁶ This modification alone would tremendously improve the ship-based performance of STOVL aircraft, and is a step toward enabling conventional fixed wing assets to operate from amphibious shipping. If rotary wing deck space and concurrent fixed-wing and helicopter operations are perceived as a hindrance, it can be alleviated by simple, proven modifications to ship-based aviation doctrine.

“The most potent and effective method of employing the JSF onboard L-class ships is to place a squadron or two (based upon the number of JSFs assigned to each squadron) on one large deck and designate this ship a dedicated fixed-wing tactical platform. This concept, currently known as a ‘Harrier Carrier’, has been proven to be the most effective means of maximizing the firepower and surge capability of STOVL jets when operating off of amphibious ships.”¹⁰⁷

This again could be used as a tremendous force multiplier that would allow all naval aviation assets to exercise their capabilities from amphibious shipping. The Marine Corps would no longer be restricted by the limited number of STOVL aircraft available to the MEU. In areas where the Carrier Battle Group could not operate, L-class shipping could be used as a floating FARP for the carrier based assets to re-arm and refuel. The amount of flexibility to be gained by allowing conventional aircraft to operate from an L-class ship cannot be matched by STOVL alone unless the U.S. Navy and Marine Corps team becomes an all-STOVL force.

¹⁰⁵ Stout, 46-47.

¹⁰⁶ Hancock, 25.

¹⁰⁷ Hancock, 33.

The conventional fixed-wing amphibious ship concept holds tremendous potential, not only to increase operational flexibility, but also to achieve a higher level of commonality within the JSF program, and to accomplish the intent of OMFTS.

“Employment of the MAGTF as a sea-based operational maneuver element optimizes its unique combined arms character; just as significantly, its overall force protection posture.... [The Marine Corps] must align its tactics, techniques and procedures with the tenets of *Operational Maneuver from the Sea*, *Ship to Objective Maneuver*, and *MPF 2010 and Beyond*. Seabasing is the thread that ties these concepts together, describing a capability which capitalized on the maneuver-ability and protection afforded by the sea. The 21st Century MAGTF commander will exploit the seabased nature of his force to execute precise, focused combat actions, rather than participate in continuous, drawn-out operations.”¹⁰⁸

As a point of observation, the exclusive availability of 10 to 20 STOVL aircraft appears to be more precipitous of continuous, drawn-out operations than does the capability to employ an entire carrier’s worth of TacAir assets in intervals from a seabased FARP. New, advanced L-class ships are being designed and built now.¹⁰⁹ The Navy’s reluctance to add ski-jumps and arresting gear to L-class shipping, combined with the Marine Corps’ fear of losing STOVL TacAir, will most likely prevent the creation of a conventional fixed-wing capability in these new amphibious ships.

HIGH SORTIE RATES

The F-16s of the 363d Tactical Fighter Wing demonstrated during Desert Storm that conventional aircraft can generate a tremendous amount of sorties with minimal response time from forward bases. And, in combination with FAC(A)s, the target area time can be reduced significantly for attack aircraft, thereby allowing more sorties of a shorter duration. This is a viable, proven alternative that exists with our current assets and does not require STOVL. To

¹⁰⁸ *United States Marine Corps Warfighting Concepts for the 21st Century*, IV-17.

¹⁰⁹ Dally interview.

enhance this capability and incorporate future technology, the Marine Corps may expand on the sea-based FARP concept.

A conventional fixed-wing capable L-class ship would probably be operating at maximum capacity just launching and recovering its own aircraft, so the added burden of turn-arounds for carrier based aircraft could be prohibitive. However, a system could be devised wherein aircraft land on the seabased FARP with a small amount of fuel and re-arm aboard ship in a minimal amount of time (Harriers boasted a 6 minute re-arming time during surge operations in Desert Storm). They could launch with a heavier ordnance load than would be possible when carrying a full fuel load, and then refuel from an airborne tanker enroute to the target area.¹¹⁰ FAC(A)s in the target area could locate and mark targets, and expedite the flow of air traffic through the target area. By employing fixed-wing tanker assets and airborne Tactical Air Coordinators (TAC(A)s) the deck cycle of organic and visiting TacAir could be coordinated with target area operations, arriving and departing carrier traffic, and the eventuality of emergency aircraft.

If the Marine Corps wants to increase its sortie generation capability by an order of magnitude, STOVL is not necessarily the best answer. Innovation and modification of amphibious platforms could enable the full capabilities of the MEU and a remote carrier battle group to be brought to bear on the enemy at the decisive place and time.

SURVIVABILITY

As demonstrated earlier, the concept of dispersed sites has tremendous potential to create more survivability problems than it solves. The vulnerability of forward sites and their extensive logistics trains, whether they be ground- or air-based, presents a force protection obstacle that

¹¹⁰ Dally interview.

our armed forces are not prepared to deal with. The Marine Corps Warfighting Concepts document addresses this issue:

“One does not have to look back far in time to find instances where shore-based US expeditionary forces have suffered severe losses, even while participating in ‘peacekeeping’ missions. The fact is that fixed installations and facilities are more vulnerable than those which are seabased.”¹¹¹

As the Marine Corps exists today, its sea-based and central airfield based assets are far safer, because of the protection afforded by surface-to-air missile capability and sheer distance from the enemy, than forward, dispersed sites and their lines of communication. The OMFTS concept lists forward land basing as an option of last resort. The document states that Marine air will “be seabased to the maximum extent practicable,” and that operations ashore are “not a preferred course of action, as it subjects personnel and equipment to many vulnerabilities and increases strain on the combat service support system.”¹¹² As of now, only STOVL can boast the flexibility and survivability of seabased operations, independent of the aircraft carrier. The development of conventional fixed-wing capable amphibious ships, on the other hand, would solve this problem for the conventional JSF and at the same time provide more fire support flexibility to the ground combat element.

THE TRUE ALTERNATIVE

The real answer to flexibility, sortie generation, and survivability does not rely on the improvement of STOVL capabilities. When it comes to land based operations, conventional aircraft in their current state of capability can perform as well as, and in most cases much better than their STOVL counterparts. The difference then is in sea-based operations when the MEU must operate remotely from the aircraft carrier. The real answer to flexibility, sortie generation,

¹¹¹ *United States Marine Corps Warfighting Concepts for the 21st Century*, IV-16.

¹¹² *United States Marine Corps Warfighting Concepts for the 21st Century*, IV-12.

and survivability stems from innovations that will allow all fixed-wing TacAir assets to operate from sea-based platforms in the littorals, closer to the battle than the carrier can operate, yet distant from enemy interference. This will not only allow the Marine Corps to operate a more capable aircraft, but will also take advantage of the full compliment of carrier based aviation should the need arise. An added benefit is the increased commonality among the services in JSF design, which is a main goal of the program from its inception. The capability exists for the Navy and Marine Corps team to make this concept a reality; the only obstacles are the Navy – unwilling to innovate its amphibious force, and the Marine Corps – afraid that the disappearance of STOVL will mark the end of Marine TacAir.

LOOKING AHEAD

The laws of physics place certain constraints on what technology can accomplish in regard to STOVL. As STOVL technology improves, so does the technology of conventional aviation, and the fact is that STOVL equipment comes with a penalty in the form of weight and airframe space. The weight and space penalties are compensated for by reducing the payload and fuel capacity of the aircraft. Additionally, requiring an aircraft to land vertically consumes fuel that would otherwise translate into increased combat radius. The JSF program has made great strides in many areas of aviation warfare, particularly in target area survivability and the exploitation of advanced weapons and targeting systems. But the STOVL version still faces challenges that add complexity to the design and cost to the overall program. Until alternative energy sources and directed energy weapons are commonplace within the TacAir community, it is doubtful that a true STOVL fixed wing aircraft will ever perform on par with its conventional counterparts.

In the meantime, the armed services as a whole are missing out on an opportunity to increase the warfighting effectiveness of tactical aviation. Having a few aircraft capable of operating from very short runways and amphibious shipping is nice, but extending that capability to all TacAir platforms at a very small cost would be much better. By adding ski-ramps and arresting gear to new and existing L-class ships and to the EAF 2000, the reach and flexibility of U.S. military aviation can be increased to a level that STOVL could never achieve. Navy and Marine Corps leadership must become enablers and not obstacles to the advancement of expeditionary aviation.

The Marine Corps must get over the unfounded fear that if STOVL goes away, so does the rest of Marine Corps TacAir. STOVL TacAir has done nothing in combat that conventional

aviation could not have accomplished. What makes the USMC unique is not a piece of machinery or a kind of technology. The Corps' utility to the United States depends on combat effectiveness, which stems from making smart choices. The future foundation of Marine Corps fire support must be built upon the rock of proven performance, and not in the shifting sands of novelty. The laws of physics dictate unwaveringly that the penalties of STOVL are a reduction in performance. The wiser choice by far is to invest time, effort and resources into the development of short takeoff and landing techniques that can be utilized by more conventional aircraft. By doing this, future aircraft will inevitably out-perform STOVL in payload, combat radius, time on station, survivability, maintainability, safety, and most importantly, mission effectiveness.

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